Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
MITIGATION OF ORBITAL DEBRIS IN THE NEW SPACE AGE	)	IB Docket No. 18-313

COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

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SUMMARY

As one of the world's fastest growing providers of launch services and as a licensee of a non-geostationary orbit ("NGSO") satellite system, maintaining a clean orbital environment is fundamental for every aspect of SpaceX's business. SpaceX is proud to have contributed to the unprecedented surge in investment in space technologies and space-based services in the United States. Innovation in advanced space and ground technologies combined with dramatic improvements in the efficiencies and costs of both satellite manufacturing and space launch are making possible a new generation of space-based services, including—but not limited to—a new generation of satellites to deliver high-speed, low-latency broadband connectivity. These cutting-edge satellite systems offer the potential to deliver substantial new benefits to the public by providing high-quality services to the far reaches of the country and the globe.

The accelerated pace of satellite authorizations over the past few years demonstrates the timeliness of the Commission's inquiry into how these new satellite systems operate responsibly. At the same time, steps taken by any government agency that affect this burgeoning industry must strike a careful balance that protects a safe environment while preserving the conditions that have led to this truly American revolution in commercial space.

The Government Should Set High-Level Policies.

To strike this balance, the government should pursue strong but simple policies:

1. Operators should not create new persistent debris.
2. Operators should limit their satellites' time on orbit following the end of their mission lifetime.
3. Systems operating in orbits near and above the International Space Station ("ISS") must perform to higher standards of capability that protect human life and important assets.

Together, these policies will ensure a safer space environment into the future. But critically, even if the government adopts these strong policies, no efforts to safeguard space will

be effective unless they are applied broadly and adopted internationally. While international adoption is outside the jurisdiction of any one nation, the Commission can take an essential first step to affect the broader space environment by applying its orbital safety and debris rules equally for U.S.-licensed systems and to those foreign-licensed systems seeking Commission approval for U.S. market access. Rules that apply selectively only to U.S. licensees will encourage satellite operators to forum shop among other countries, leading to satellite systems with the worst safety profile seeking licenses in countries with the loosest or least mature rules and undermining U.S. efforts.

If Additional Rules are Adopted, They Should Follow Basic Principles.

Rules should be verifiable and enforceable. Any rules should rely on verifiable and enforceable performance metrics rather than unnecessarily prescriptive or specific technology requirements. Simply put, the government should define what needs to be accomplished, rather than prescribing how these goals must be achieved in any given situation. The industry then has both the mandate and the flexibility to execute against these high-level performance metrics by developing innovative and cost-effective solutions. In contrast, overly prescriptive or specific metrics, particularly ones that extend beyond current testing capabilities, provide a sense of false precision that will stifle innovation and promote gamesmanship rather than real solutions.

Rules should favor disclosure of relevant information. Any rules should favor sharing of operational data such as orbit raise and lower schedules, reentry targets, demise predictions, and other relevant data to enrich awareness and knowledge of the space environment for other systems. Because operators themselves have the most accurate information on the location and functionality of their own systems, they must bear the primary responsibility to avoid conjunctions. Armed with the proper knowledge and functionality, operators can either take evasive action themselves or

alert others of their positions. But to responsibly engage in effective avoidance maneuvers, the location of satellites within a constellation must be transparent to other operators through a centralized entity such as the Combined Space Operations Center ("CSpOC").

Rules should be applied on a per-satellite basis rather than arbitrarily applied in aggregate to constellations of certain sizes or orbital paths. Any rules should apply equally to similar spacecraft, rather than applying differently based on who operates an individual satellite or what orbital path they choose—except as necessary to protect the ISS and surrounding areas. To maintain consistency and efficacy across all types of space systems and all orbits, the government should reject proposals that single out any specific space architectures. For instance, some have proposed to put the burden for maintaining a clean orbital environment on just a few NGSO constellation operators based on the number of satellites they operate. But to be effective, these policies should instead apply on a per-satellite basis, versus aggregate system metrics that depend on arbitrary definitions of constellation size, category or orbital regime used.

The government should prioritize human life on the ground. Because human life is paramount, the government should phase in a standard of negligible risk of casualty from de-orbiting satellites. Unlike other forms of broadband infrastructure deployment, satellites re-entering the Earth's atmosphere have never caused a human casualty. Nonetheless, to maintain this track record, the government should move towards effectively no risk of human casualty.

Rules must recognize that forecasts of demise time are based on several factors, not just altitude. The Commission correctly recognizes that certain lower orbits, such as the altitudes at 650 km and below, have innate safety benefits. But the safety profile of a new system does not rest solely on its selected altitude; safety also depends on other factors, such as the mass-over-area ratio for each spacecraft. The Commission should identify and require disclosure of such

additional factors by applicants, as well as decay time for satellites at solar maximum and minimum and in controlled and tumbling attitudes, so that it can make a more complete assessment of the overall safety of the proposed system.

SpaceX supports the Commission's effort to maintain a safe space environment for today and into the future. By adopting strong policies that follow straightforward principles, the government can work as a partner with launch providers and the entire satellite industry to protect this precious natural resource and maintain the U.S. leadership position in commercial space.

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COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

Space Exploration Technologies Corp. ("SpaceX") hereby responds to the Commission's request for comment on its comprehensive reexamination of existing orbital debris mitigation rules.[1] SpaceX supports the Commission's efforts to improve and clarify its licensing rules to reflect the revolution in commercial space that has taken place since the Commission last updated its rules fifteen years ago. The Commission is right to explore whether its rules for debris mitigation accurately reflect its legal authority and the developments in technology and the market.

INTRODUCTION

Since its inception, SpaceX has leveraged American innovation, technical savvy, and its integrated, iterative culture to provide the most advanced launch and spacecraft systems in history. Through these efforts, SpaceX's Falcon family of launch vehicles has provided dependable and affordable rides to space for the National Aeronautics and Space Administration ("NASA"), the Department of Defense, and the world's most sophisticated commercial satellite manufacturers

[1] *Mitigation of Orbital Debris in the New Space Age*, Notice of Proposed Rulemaking and Order on Reconsideration, FCC 18-159, IB Docket No. 18-313 (rel. Nov. 19, 2018) ("NPRM" or the "Proposal").

and operators. SpaceX also regularly conducts resupply missions for NASA to deliver cargo to and from the International Space Station ("ISS") with its Dragon spacecraft, which requires operations in close proximity to the ISS. To date, SpaceX has successfully launched its Falcon rockets 69 times; since 2017 SpaceX has launched more than 65 percent of all launches from U.S. soil and the company's launch manifest represents well more than 60 percent of the worldwide commercial satellite launches. SpaceX achieved the world's first re-flight of an orbital class rocket in March 2017 and, since then, has successfully recovered 35 Falcon 9 boosters on land or at sea, and re-flown 20 Falcon 9 first stages.

Last year, SpaceX launched the most powerful operational rocket in the world by a factor of two, the Falcon Heavy, and landed the two side boosters of that vehicle simultaneously, a feat never accomplished—nor even attempted—in history. Just a year later, SpaceX is set to launch the Falcon Heavy for its first commercial mission. With booster re-use now routine, SpaceX took another unprecedented step by reusing a Falcon 9 booster for a *third* time and has now done so two more times with a fourth scheduled for later this year. Looking forward, NASA has selected SpaceX to launch in the next few months the first American astronauts from U.S. soil on an American rocket since the Space Shuttle was retired in 2011.

SpaceX is now taking its nearly two decades of experience in cost-effectively deploying large, complex space systems for other operators to develop its own broadband non-geostationary orbit ("NGSO") satellite constellation from the ground up. With a tightly integrated strategy—linking design, development, production, test, launch, and operations—SpaceX is pursuing a unique approach to an iterative low-Earth orbit constellation designed to overcome the challenges of cost and inefficiencies that have plagued past NGSO constellations. SpaceX's in-house launch capability leverages the reusable Falcon 9 system to provide the company with ready access to

space, further enabling continuous technology enhancements in the spacecraft with ongoing constellation replenishments and upgrades.

Maintaining a clean orbital environment is fundamental for each of these essential aspects of SpaceX's business, which is why SpaceX is committed to spacecraft designs and operational practices that safeguard all operating spacecraft and preserve orbital resources for future exploration and development. SpaceX's history is imbued with a deep understanding of the responsibility of space operations and the necessity to preserve the space resource that we share with others. As such, SpaceX is pleased to see the emphasis on updating space safety and sustainability principles and regulations throughout the Federal Government, including the Commission, the administration, and Congress.

Sensible safe space rules should ensure operators act responsibly while leaving in place the economic conditions that spurred the innovation and economic growth that put the U.S. in the leading position in commercial space. Because the Commission has licensed commercial communications satellites—which make up about a third of spacecraft in orbit[2]—the FCC is now positioned to play an important part in the larger initiative to ensure space stays safe for current and future operations.

The government is building its broader efforts on the foundation laid by the Space Policy Directive-3 ("SPD- 3"), which the president released last year to set out the National Space Traffic Management Policy.[3] Within this larger context, the Commission is properly taking this

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2 *See* Satellite Industry Association, 2018 STATE OF THE SATELLITE INDUSTRY REPORT (June 2018).

3 *Space Policy Directive-3, National Space Traffic Management Policy*, Presidential Memorandum (June 18, 2018), https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/.

opportunity to reconsider its authority and how its licensing actions interact with efforts at other agencies.[4]

While SpaceX takes no position here on the best approach for expert agencies to collaborate and interact, it strongly supports any efforts towards interagency coordination and the pooling of expertise across space operations. This coordination can ensure that the multiple agencies that oversee companies operating in space apply consistent principles across the U.S. Government and establish which Federal agency has the appropriate lead for a given activity, consistent with their statutory authority. This effort will help avoid confusion, eliminate regulatory duplication, streamline processing, and avert conflicts in requirements across agencies.

While several parts of the Federal Government will ultimately play critical roles in ensuring safe space and SpaceX will contribute its views to them at the appropriate time, SpaceX takes the opportunity in the public docket created here by the Commission to offer its views. These comments relate only to spacecraft regulated by the Commission and do not necessarily apply to spacecraft regulated by other agencies. For instance, second stages of launch vehicles that are regulated by the Federal Aviation Administration should not be subject to duplicative regulations from the FCC.

I. THE COMMISSION SHOULD SET HIGH-LEVEL REQUIREMENTS FOR INDUSTRY TO ACHIEVE.

The revolution in commercial space is gaining momentum at a rapid pace. While many thought innovations like reusable rockets seemed outlandish just a few years ago, SpaceX has now proven the technology repeatedly, landing 35 times and reusing the same booster three times for

[4] SpaceX agrees with the Commission's suggestion that it should closely review the statutory basis of its authority to regulate the release of orbital debris. NPRM at ¶¶ 15-16. Robust regulatory safeguards are critical to ensure the continued safety of space. The Commission must ensure that any rules is adopts are based on clear statutory authority that is appropriately integrated within any broader federal regulatory regime.

three separate commercial missions. Others in the industry are pushing through technological boundaries as well. In the midst of these kinds of paradigm shifting advances, unduly prescriptive or specific regulations may become antiquated and even counterproductive overnight. Worse, unnecessarily specific regulatory metrics could force the industry to build to regulation rather than innovating its way to a shared goal of a safer orbital environment. Innovations for reliability and safety often outpace regulatory schemes, which can become outdated quickly.

In these circumstances, the government should instead set clear overarching policies and then implement rules if necessary to support those high-level objectives. These rules should be crafted to create incentives for industry to invest in new technologies and methods that mitigate debris and improve the orbital environment. With the government setting the principles and the industry investing in innovation to implement them, the private and public sectors can work hand in glove to employ their respective expertise to protect the space environment today and into the future.

Specifically, the government should establish guiding policies:

1. Operators should not generate new persistent debris.
2. Operators should limit their satellites' time on orbit following the end of their mission lifetime.
3. Systems operating in orbits near and above the ISS must perform to higher standards of capability that protect human life and important assets.

By setting these attainable and measurable objectives, the government will not only protect current orbital operations, but also provide the certainty necessary for companies to invest in achieving large-scale dreams like making humanity a truly spacefaring species.

As a primary goal, operators should be required to take all steps necessary to avoid generating debris that will persist in orbit for more than a few months. This goal recognizes that the responsibility of operating in space includes both providing cutting-edge services for people

on Earth, while also maximizing the potential for future space exploration and operations. Recognizing that complete elimination of debris on every mission may not be fully attainable, policies should reflect the differences in persistence and size of that debris and the likely impact on other operators or missions. Long-lasting debris that survives for decades, centuries, or even millennia causes more harm than objects that the atmosphere sweeps away quickly, so those who leave objects in orbit should face stiffer penalties than those who generate incidental fragments that rapidly de-orbit. And while generation of small debris over time may be unavoidable, rules should apply at minimum to debris large enough for the best technology at the time to track.[5]

But the risk of cluttering space is not limited to particulates or parts of damaged spacecraft. The abandoned remains of discarded satellites still drift through useful orbits, endangering valuable operations. The government should create incentives for operators to actively remove those spacecraft from orbit as soon as they complete their useful lives. Policies should prohibit operators from leaving satellites in orbit beyond their authorizations without specific approval from the licensing agency. A necessary corollary to this objective is that demise time should be tied to the operational lifetime of the spacecraft. The current demise time of twenty-five years is significantly longer than necessary for most contemporary missions, given current technology.[6] A safer general demise time would be set as short as possible, but in no instance longer than the operational life of the satellite plus five years. As the number of satellites in orbit increases, rules that hasten demise will remove inactive objects and promote a safer orbital environment.

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[5] The Commission also seeks comment on what qualifies as "large" or "small" debris. To the extent that distinction is necessary, the Government should base its review on whether the object is trackable by an entity such as CSpOC. *See* NPRM ¶ 26.

[6] *See* NPRM ¶ 59.

Finally, the areas around and immediately above the ISS are home to precious cargo, especially human lives. Anyone wishing to deploy in those orbits has a heightened obligation to take special care to operate responsibly. With SpaceX's recent successful demonstration of the next-generation Crew Dragon, the first new American human spaceflight vehicle to orbit, the U.S. is now poised to see the first private company bring astronauts to the ISS later this year. But that mission, though momentous, is just the beginning for commercial human spaceflight. The orbits around the ISS—specifically those ranging from 300 km to 600 km—will also see other crewed missions in the near future.

While this burgeoning new age of space exploration and human spaceflight intensifies the sensitivity of these orbits, they have also become the destination of choice for a quickly expanding fleet of non-propulsive and even non-maneuverable satellites. These satellites have demonstrated a clear value to both experimentation and commercial innovation, but this proliferation of satellites at orbits near the ISS or at an altitude low enough to decay within the ISS's lifetime demands scrutiny to avoid a steady rain of uncontrolled de-orbiting satellites and resulting debris. The potential deluge of disorganized de-orbits could present a significant collision concern for the ISS as well as all spacecraft below or passing through its operational altitude. From a launch perspective, a large number of such non-maneuverable satellites complicate the deployment of any spacecraft that transits through the sub-ISS altitudes. In fact, the Commission specifically raised these potential risks in its smallsat proceeding.[7]

[7] *See Streamlining Licensing Procedures for Small Satellites*, Notice of Proposed Rulemaking, 33 FCC Rcd. 4152, ¶ 34 (2018).

To address these concerns—protecting the ISS, preserving the viability of human space travel, and ensuring the opportunities of future space exploration—operators planning to deploy satellites above and around the ISS should be required to have propulsive capabilities.

II. THE COMMISSION CAN MAKE SPACE SAFER AND DISCOURAGE FORUM SHOPPING BY APPLYING THE SAME RULES TO U.S.-LICENSED SYSTEMS AND FOREIGN SYSTEMS SEEKING U.S. MARKET ACCESS.

By its very nature, space defies geographic and political boundaries. While this cross-border quality can bring many benefits to American consumers, it also means that solutions to address the space environment will be ineffective if applied to U.S. commercial satellite operators alone. In this case, setting orbital safety goals and corresponding rules will be undermined unless they apply to all systems—or at least as many systems as possible, including satellites operated by Federal entities. As an important step towards that end, the Commission should ensure that any updates to its space safety requirements apply to both U.S.-licensed systems and foreign-licensed systems approved for U.S. market access.

Operating a satellite system comes with a responsibility to protect the orbital environment, but this responsibility adds cost to operations. Applying rules to reflect this responsibility and the obligation to invest and deploy safeguards solely to U.S.-licensed satellite operators would potentially deter satellite operators from applying for licenses in the U.S. and thereby undermine the Commission's goals. While SpaceX is proud to be licensed in the U.S., other systems may try to avoid these costs and shirk their responsibility by seeking a license in a country with less stringent orbital debris requirements.

Fortunately, the U.S. has a critical tool to combat this tendency by applying its rules to any system wishing to provide service in the U.S.[8] This is an effective tool to extend the ambit of the Commission's policies because many operators will seek access to lucrative opportunities in the U.S. market even if they would prefer to minimize the cost of orbital debris mitigation compliance. The Commission should therefore apply mitigation rules and require orbital debris plans that comply with U.S. objectives and rules for all systems seeking Commission approvals to provide services or operate facilities within the U.S.

Orbital safety is an international objective, and the U.S. should do all it can to make sure its rules are applied consistently.[9] The Commission should not create loopholes in well-considered and transparent U.S. regulations by exempting foreign operators that are serving U.S. consumers.[10] Such arbitrary treatment would gut the Commission's efforts, penalize U.S. companies, drive U.S. innovation overseas, and negate U.S. leadership in space safety.

III. ANY RULES IMPLEMENTING THE COMMISSION'S GOALS SHOULD BE VERIFIABLE AND ENFORCEABLE, FAVOR DISCLOSURE, AND APPLY ON A PER-SATELLITE BASIS.

By establishing the three important goals described above and applying them consistently to all operators within the U.S., the government will take a significant step towards maintaining sustainable space into the future. If the government chooses to also establish concrete regulations in support of these goals, it should adopt performance-based metrics that are both verifiable and enforceable, while avoiding prescriptive or specific mandates that impose unnecessary or even counterproductive technical requirements. These rules should promote sharing of information that

8 *See* NPRM at ¶ 85.

9 *See id.* ¶ 86.

10 *See id.* ¶ 87.

could aid in collision avoidance and tracking. Finally, rules should be applied on a per-spacecraft basis, rather than applying arbitrary distinctions based on orbital paths or type of operators.

a. Rules Should be Based on Verifiable and Enforceable Performance Metrics, Not the False Precision of Ex Ante Requirements.

Ensuring a clean and safe orbital environment into the future cannot rest with any one entity—it will require cooperation between governments, space operators, manufacturers, and launch providers, with each taking on a role specific to its expertise. For the government, that responsibility should translate into setting guiding principles and objectives, and only then followed by verifiable and enforceable rules necessary to yield those desired outcomes. These rules should be straightforward and balance the government's oversight role with the goal of continuing to encourage innovation and economic development in space.

Once the government identifies its key overarching goals, any rules should set the proper incentives to encourage industry to continue to explore and develop the best methods to meet these goals. The driving pace of technological development can quickly render moot directives that are unnecessarily prescriptive or technology-specific. Worse, requirements that reference certain technologies, techniques, or unnecessarily specific metrics could be counterproductive and freeze innovation as industry builds to the regulation rather than to the ultimate safety goal. Instead, encouraging industry to determine the best way to meet the government's objectives will ensure that operators develop and take advantage of new technological advances.

For instance, active debris removal is not technologically feasible using today's techniques, but the right incentives will push industry to develop and use this technology in the future. To ensure that the industry continues to innovate, public interest goals should be accompanied by the carrots of eased regulatory restrictions for those who embrace their responsibility alongside the sticks of rigorous enforcement.

In its proposal, the Commission put forward a number of extremely specific metrics to assess important safety issues, such as for spacecraft reliability and collision avoidance capabilities. While well-intended, these types of metrics simply are not verifiable by the Commission—or in certain circumstances even by the spacecraft operators themselves—in advance of launch. Environmental and testing data gaps can be responsible for considerable error in a given reliability analysis and technology is not able to prove out reliability to the level suggested in the Commission's proposal.[11] For example, although many operators could likely develop a model and simulation software to confirm they are able to comply with a potential 0.01% collision risk limit, such metrics are extremely sensitive to input parameters, the true values of which are not well established.[12] Thus, establishing such a threshold could invite technical compliance through fine-tuning of a computer model, rather than investment in technology and more scrutiny of real-world operational characteristics.

As an example, impacts on-orbit can occur at relative velocities of up to 8 km/s with orbital debris, and ~70 km/s with micrometeorites. In contrast, terrestrial hypervelocity guns are generally limited to a maximum speed of ~8 km/s. Calculating performance at higher impact velocities requires extrapolations that carry non-trivial error. This type of analysis can be useful in certain situations for a manufacturer to test its own spacecraft design, but it lacks the rigor necessary for a regulatory requirement given its limited fidelity to actual conditions. Because the actual speeds of encounter in the real world fall well beyond the range of current testing capability, a prescriptive requirement to conduct and report the results of such testing would divert resources away from

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[11] *See* NPRM ¶ 27.

[12] *See also* NPRM ¶ 23 (recommending that satellite operators be required to have "limited the probability of accidental explosions during and after completion of mission operations.") Operators have no reliable means to calculate such a probability.

improving spacecraft while still relying on unverifiable and undependable extrapolations that do not yield the certainty intended—and misleadingly conveyed—by the metric.

This false precision will do little to improve orbital safety and could lull the government, the industry, and the public into a false sense of safety. In fact, unduly burdensome ex ante metrics will tempt operators to simply indicate that they believe that their spacecraft could meet those requirements without any testing. Or they may conduct the testing, but do so in a way that maximizes the probability of a positive result, within the letter of the law. Government agencies would have no mechanism to verify these attestations and no means to enforce against those who were wrong. These types of unverifiable attestations invite gaming of the regulatory process, and false precision could lead to regulations that are both over- and under-inclusive and forestall more achievable options to make space safer.

Once the government adopts verifiable requirements, it should tie its rules to a rigorous enforcement framework that penalizes the generation of debris and reflects the seriousness of the harm such debris inflicts. For instance, while CSpOC or another third party should be the primary party charged with tracking debris, an effective enforcement structure should encourage operators to report immediately whenever debris is generated.

b. Rules Should Favor Transparency and Require Operators to Disclose More of Their Mitigation Plans.

Operators of satellite systems must bear the primary responsibility to avoid conjunctions and to mitigate the creation of any new orbital debris. Operators themselves have the most accurate information on the location and functionality of their own systems, putting them in the best position to enable other systems to operate safely in adjacent or overlapping orbits. Armed with the proper knowledge and functionality, operators should be able to either take evasive action themselves or alert others of their positions if necessary. But to responsibly engage in effective

avoidance maneuvers, systems must be largely transparent to each other—ideally through a centralized third-party such as CSpOC.

To ensure the necessary level of transparency to avoid conjunctions, the government should implement rules that require (or reward) regular disclosure of precise updates on satellite orbital parameters, satellite health, and ability to perform collision avoidance maneuvers. This increased disclosure serves the dual purposes of allowing other operators to navigate risks better while discouraging all operators from cutting corners and engaging in bad practices.

To achieve this level of transparency, the Commission should require applicants for U.S. satellite authorizations—both NGSOs and GSOs—to describe the extent to which their satellites will be able to avoid collision. For example, as the Commission has proposed, an application for authorization could include an explanation of the number of collision avoidance maneuvers the satellite is capable of making as well as any other means the satellite may have to avoid conjunction events.[13] The Commission should also adopt its proposal to require applicants that intend to dispose of their spacecraft by a means other than passive atmospheric demise within a set timeframe to provide information on a per-satellite basis about how the operator will successfully dispose of its satellites. For instance, if an operator plans to rely on fault tolerances, the operator should explain whether it plans to deorbit its satellites when it reaches a zero fault threshold or another method.[14] Additionally, the Commission should codify its current practice of requesting certain types of information from GSO licensees seeking license term extensions.[15]

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[13] *Id.* ¶ 39.

[14] *Id.* ¶ 46.

[15] *Id.* ¶ 65.

In addition to these disclosures as part of the licensing process, operators should also share information on an ongoing basis with an appropriate and competent repository for such data, currently the Air Force Space Control Squadron,[16] and ensure their satellites are trackable. This information should include, but not be limited to, data regarding initial deployment, ephemeris, and any planned maneuvers, as well as any non-functional satellites or anomalies.[17] Systems should then certify that upon receipt of a conjunction warning the operator of the satellite will take all necessary steps to assess and to mitigate the risk of an on-orbit collision.[18] But, critically, for this requirement to be truly effective and to improve the entire space environment, it cannot be limited to U.S. licensed NGSO systems alone—this disclosure-and-avoidance requirement should extend to all spacecraft serving the U.S., regardless of orbital configuration or licensing nation.

c. To Ensure a Consistently Safe Orbital Environment, All Satellites Should Be Treated the Same Regardless of Operator.

SpaceX strongly supports the Commission's goal of making space safer for current and future uses. But to be effective, this commitment to safety must extend to everyone in the space community—the U.S. will not be able to meet these goals by requiring just a few commercial communications satellite operators to carry the burden for all. To maintain consistency and efficacy across all types of space systems and all orbits, the government should reject proposals that single out any specific space architectures or orbital paths—except as necessary to protect the ISS. A mixed approach that treats certain sized constellations or certain orbits differently will result in a cacophony of regulatory burdens that will necessarily turn on arbitrary distinctions.

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16 *Id.* ¶ 37.

17 *See id.* ¶ 67.

18 *See id.* ¶ 38.

Specifically, some have proposed to put the burden for maintaining a clean orbital environment on just a few NGSO constellation operators, based on an arbitrary number of satellites they operate. These unfounded distinctions could result in disparate regulatory treatment of satellites of equivalent capability solely because one is operated as part of a group. This yields no benefit to space safety and creates unnecessary incentives to game the system. For instance, if the government applies additional burdens only to constellations of 100 satellites or more, operators could be tempted to disguise the true size of their constellation by simply seeking multiple licenses for smaller components of their system. The net result of this gaming would be to permit a less safe space environment with multiple systems that are harder to track and to find the true owner.

Similarly, metrics taken in the aggregate across an entire constellation can result in uneven rules that actually make some satellites less safe than others. For example, the Commission asks whether applicants for NGSO satellites should demonstrate that the probability that their spacecraft will collide with a large object during the orbital lifetime of the spacecraft will be no greater than 0.001, and whether it should apply this metric on an aggregate, system-wide basis (i.e., 0.001 for an entire constellation).[19] Aside from the impossibility mentioned above of testing these standards, this metric would impose potentially widely varying requirements on satellites that are operationally equivalent, with more lax regulations applying to satellites run by some operators than others. This arbitrarily disparate treatment would create the perverse outcome of a less safe space environment than if the government applied rules on a per-satellite basis. For example, five operators of NGSO systems of 20 satellites each would be held to a lower standard than would a

[19] *Id.* ¶ 26 (if the Commission does adopt a standard on a per-satellite basis, it should be more stringent than just 0.001).

single operator of a 100 satellite system—even though the number of satellites involved in each case, and the orbital debris issues related thereto, are not distinguishable.

In contrast to these arbitrary size distinctions and ill-fitting aggregate metrics, adopting rules on a per-satellite basis better aligns incentives across all satellite operators. Per-satellite requirements would mean that each satellite is held to the same standard regardless of the operator or the size of the overall system. To the extent violations of the standard are subject to enforcement actions and fines on a per-satellite basis, the Commission will also significantly increase incentives for operators of larger constellations to take on more responsibility for collision avoidance capabilities. This, in turn, will lead the appropriate actors to improve both safety within a given constellation and in its interactions with the satellites of other operators.

IV. THE GOVERNMENT SHOULD PRIORITIZE THE SAFETY OF LIFE ON THE GROUND WHILE IMPROVING ITS EXISTING RISK MEASUREMENT TOOL.

One of the Commission's core missions is to make broadband more accessible for everyone in the United States. Unfortunately, deploying broadband creates risks to human life and human property, regardless of the technology used to deliver the service. For instance, climbing towers to install the transmitters necessary to provide terrestrial wireless services has been considered one of the most hazardous job in the country, with a casualty rate ten times that of construction workers.[20] Similarly, installing fiber for wired broadband services requires deploying thousands of trucks around the country, risking the lives of the drivers, which is also considered a particularly hazardous job. Moreover, each truck deployed creates risk not just to the trucks, but also to others

[20] Liz Day, *Feds to Look Harder at Cell Carriers When Tower Climbers Die*, PROPUBLICA (Apr. 1, 2014, 8 AM EDT), https://www.propublica.org/article/feds-to-look-harder-at-cell-carriers-when-tower-climbers-die; Ryan Knutson and Liz Day, *In Race For Better Cell Service, Men Who Climb Towers Pay With Their Lives*, PROPUBLICA (May 22, 2012, 9:52 AM EDT), https://www.propublica.org/article/cell-tower-fatalities.

on the road as well. Fortunately—unlike these other methods of broadband deployment—no satellite has ever caused a known incident of human casualty.

Nonetheless, as the number of satellites in orbit continues to grow, the government should take steps to build on this perfect record. Specifically, the government should set a predicted casualty rate for commercial satellite licensing that will effectively eliminate risk to human life on the ground. While this metric will set satellite broadband at a slight competitive disadvantage compared to terrestrial technologies that have no casualty metric associated with their deployment, it will also ensure the risk posed to human life on the ground from satellites is virtually non-existent, thereby keeping the satellite industry's perfect record in this regard intact. SpaceX recognizes, however, that a number of systems are already in development, such that equity may require that this metric be phased in over the next several years. Further, in cases where other agencies authorize space vehicles (such as second stages of launch vehicles), the Commission should defer to the expertise of the authorizing agency.

SpaceX has articulated its plan to achieve this standard with its own NGSO system even before the government implements it by moving to a completely demisable spacecraft design. After the deployment of a limited number of an initial version of its satellites that meet all existing requirements, SpaceX will transition to an architecture that employs only components for its spacecraft that will completely demise upon re-entry into Earth's atmosphere. This fully demisable spacecraft should ensure that the risk to life on the ground from SpaceX's spacecraft is effectively nil. Notably, although SpaceX has chosen full demisability, operators should have the flexibility to develop other methods to ensure the safety of life on the ground. Operators with spacecraft that do not fully demise could, for example, effectively eliminate casualty risk through targeted re-entry that ensures that satellites land harmlessly in uninhabited areas like the ocean.

To ensure the accuracy of an improved casualty metric, the government should work to improve its existing measurement tool, NASA's Debris Assessment Software ("DAS"). As configured currently, DAS does not account for a number of factors that affect the actual likelihood of harm to people on the ground from extant space debris, which could result in distortive and inaccurate results.[21] For example, DAS assumes that all people on Earth are outdoors at all times without cover. Yet, the International Association for the Advancement of Space Safety released a publication that showed that four out of five people are under shelter, and 22% is in heavy shelter.[22] According to NASA, even those in lightly-sheltered structures will have meaningful protection against the prospect of any falling space debris, up to a few kilojoules of kinetic energy.[23] This reasonable conclusion is in contrast to the DAS analysis, which uses a human casualty metric that assumes that debris with as little as 15 joules—the equivalent kinetic energy of a thrown ball—will result in human injury. The resulting distortion dilutes the safety conclusions that can be drawn from using the DAS tool alone. The DAS should be improved, so that unrealistic and overly-conservative findings do not unintentionally limit innovation without providing a countervailing benefit to safety. A better-refined tool would capture realistic human scenarios by accounting for sheltering and update the current standard of 15 joules.

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21 *See id.* ¶¶ 61-62.

22 *See* Tommaso Sgobba, *Safety Design for Space Operations*, The International Association for the Advancement of Space Safety (2013) ("*Safety Design*"), *available at* http://iaass.space-safety.org/wp-content/uploads/sites/24/2012/12/Safety-Design-for-Space-Operations.pdf.

23 NASA Standard 8719.14A at § 4.7.3(d).

V. THE COMMISSION CORRECTLY IDENTIFIED ALTITUDE AS A KEY CONSIDERATION FOR THE PROMOTION OF SAFE SPACE, BUT SHOULD AVOID DELINEATING ONE SPECIFIC ALTITUDE AS A LINE OF DEMARCATION.

As the Commission correctly observed, the atmospheric drag of altitudes closer to the Earth make them effectively self-cleaning with regard to debris and therefore generally safer for spacecraft operation. In fact, this quality led SpaceX to file a modification to its authorization to lower 1,584 of its satellites to an operational altitude of 550 km.[24] At this altitude, SpaceX can actively deorbit its spacecraft within weeks, but even in the unlikely event that an individual satellite fails, the atmospheric drag would lead to passive demise within months, leaving the orbit cleaner and safer.

But considering only a set altitude as a demarcation line will not fully account for all of the attributes that determine the safety of a given system. The safety profile of a constellation is sensitive not just to the altitude, but also to the actual design of the spacecraft, where ratios of mass to area can vary greatly across different spacecraft, and even spacecraft orientations, and can affect whether the satellites' orbits will passively decay in an acceptable period. Rather than pegging rules only to the altitude of a system, the government should consider performing a more accurate and holistic evaluation of whether the satellites can be expected to de-orbit through passive decay in a period that is acceptable.

For the government to make this assessment, applicants planning to deploy a satellite system at any altitude should specify why they have chosen that particular orbit. This explanation could include characteristics of the planned constellation such as the number of satellites, the area-to-mass ratio, and how long they plan to remain in orbit, both while undertaking their primary

[24] *See* Application, IBFS File No. SAT-MOD-20181108-00083 (Nov. 8, 2018).

mission and following completion of that mission. Applicants should also describe how their planned system will interact with the existing orbital environment, such as the level of existing debris.[25]

CONCLUSION

SpaceX supports the Commission's efforts to maintain a safe space environment for today and into the future. To accomplish this shared goal, the government should set three overarching objectives: (1) operators should not create debris; (2) operators should not leave spacecraft in orbit after their operational lives; and (3) operators should take special care to protect the lives and other sensitive operations around and above the ISS. By empowering operators to find the best way to reach these objectives, rather than imposing prescriptive or specific technology requirements, government and industry can work as partners to protect space and maintain the U.S. position as the leader in commercial space.

Respectfully submitted,

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[25] *See* NPRM ¶¶ 31-31.